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(54) SHAPE MEMORY METAL LATCH HINGE DEPLOYMENT METHOD

(75) Inventors: **David A. Hinkley**, La Mirada, CA (US); **Edward J. Simburger**, Agoura, CA (US)

(73) Assignee: **The Aerospace Corporation**, El Segundo, CA (US)

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(51) **Int. Cl.**7 .... **E05D 1/00**

(52) **U.S. Cl.** **29/11**; 29/447; 29/458; 148/563; 148/402; 16/225; 16/385

(58) **Field of Search** 29/11, 428, 447, 29/458; 148/563, 675, 669, 402; 16/225, 372, 385

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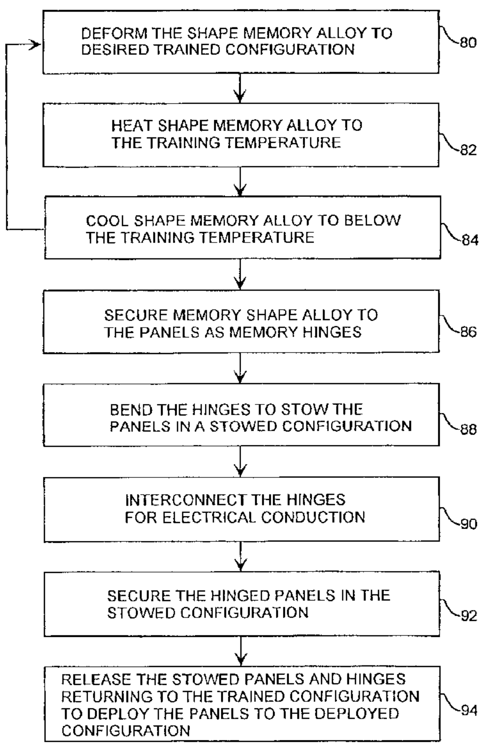
Primary Examiner—David P. Bryant
Assistant Examiner—Jermie E. Cozart
(74) *Attorney, Agent, or Firm*—Michael Reid

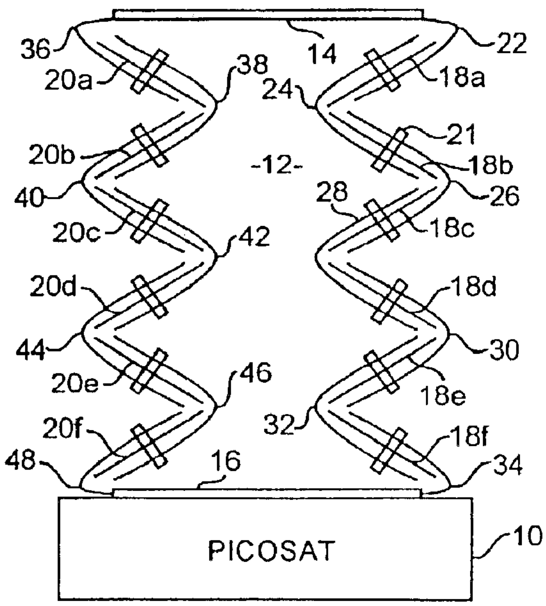
(57) **ABSTRACT**

A conductive hinge is made of a superelastic shape memory alloy such as nitinol (NiTi) having a large elastic strain limit for enabling the hinge to bend to a small radius during stowage and flexible return to a trained rigid hinge position by training the shape memory alloy to assume a predetermined deployed configuration when released from a stowage configuration. The hinge is trained by forging at a temperature above a training temperature. The hinge is stowed and released in the superelastic state to deploy solar cell panels as the hinges unfold to the trained deployed configuration.

13 Claims, 6 Drawing Sheets

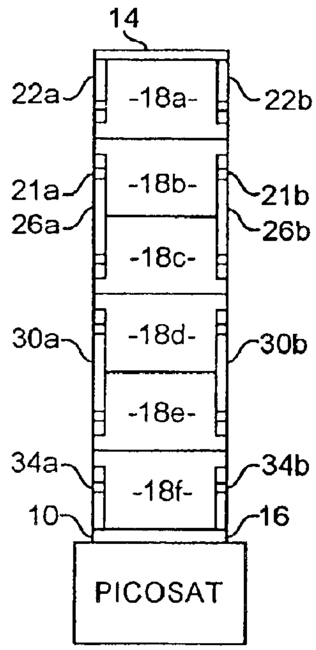


METHOD OF DEPLOYING SHAPE MEMORY ALLOW HINGED PANELS



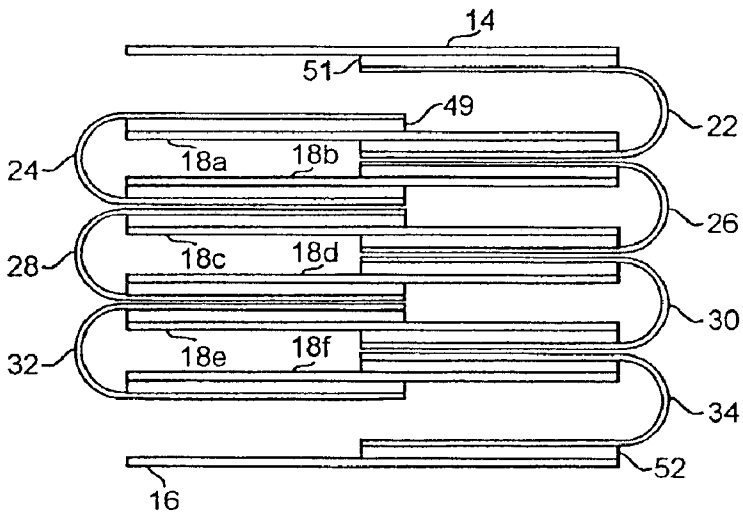
PICOSAT SIDE VIEW

FIG. 1A



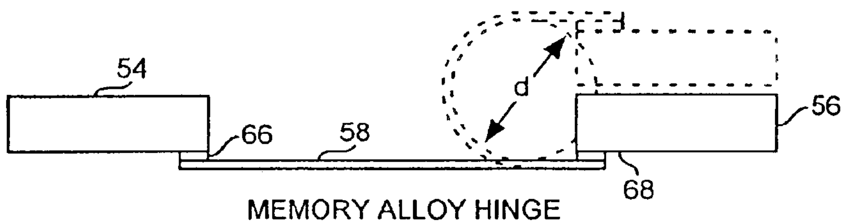
PICOSAT FRONT VIEW

FIG. 1B



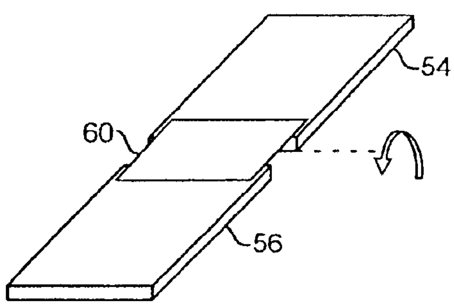
STOWED ARRAY

FIG. 2



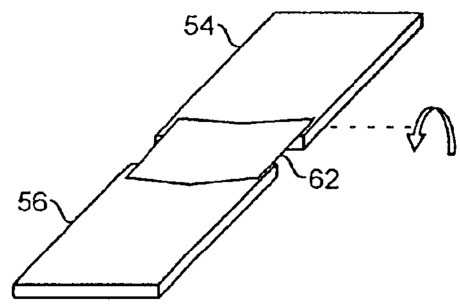
MEMORY ALLOY HINGE

FIG. 3



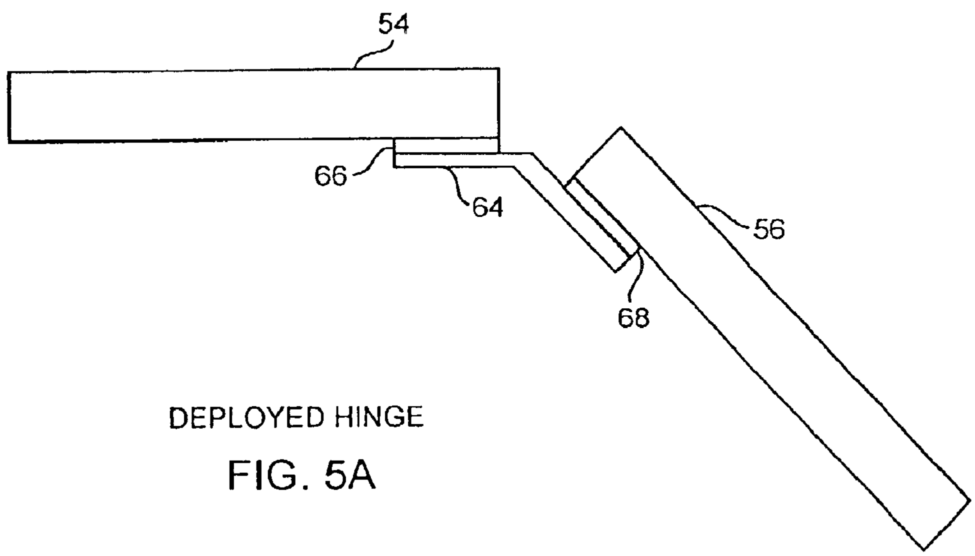
FLAT NITINOL HINGE

FIG. 4A



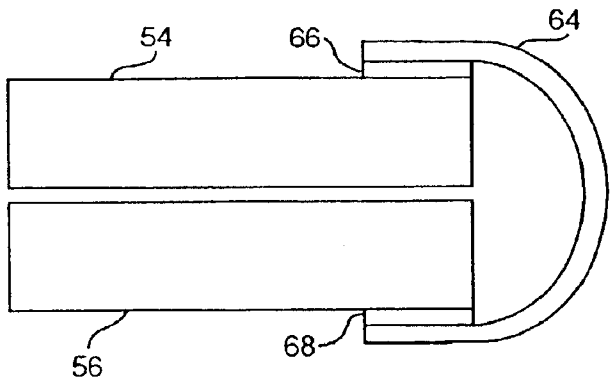
SCALLOPED NITINOL HINGE

FIG. 4B



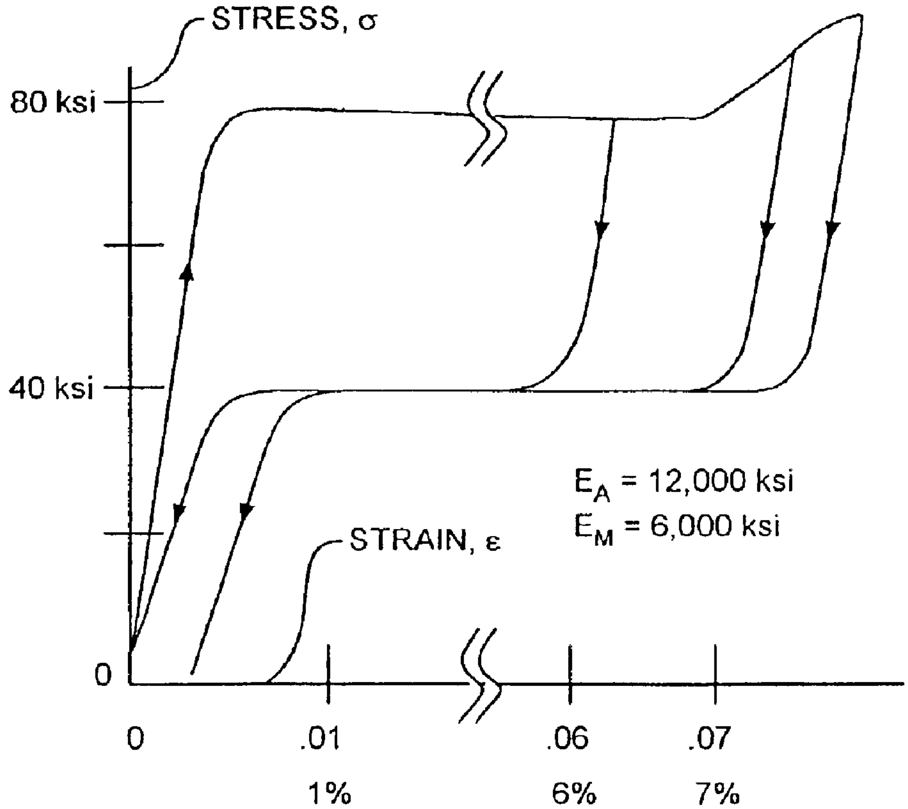
DEPLOYED HINGE

FIG. 5A



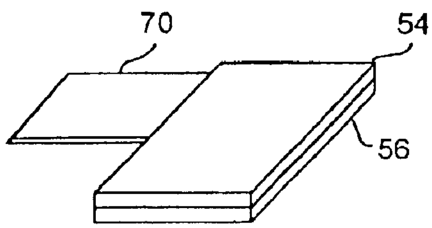
STOWED HINGE

FIG. 5B



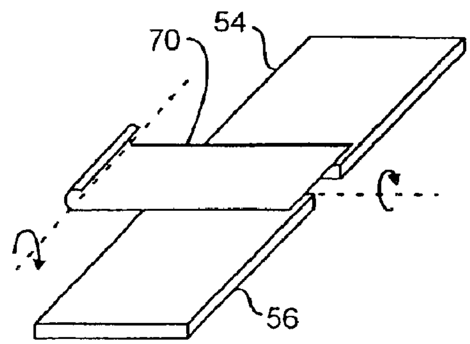
NITINOL SUPERELASTIC STRESS-STRAIN CURVE

FIG. 6



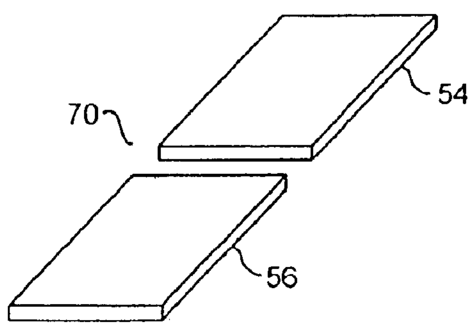
CLOSED LATCH

FIG. 7A



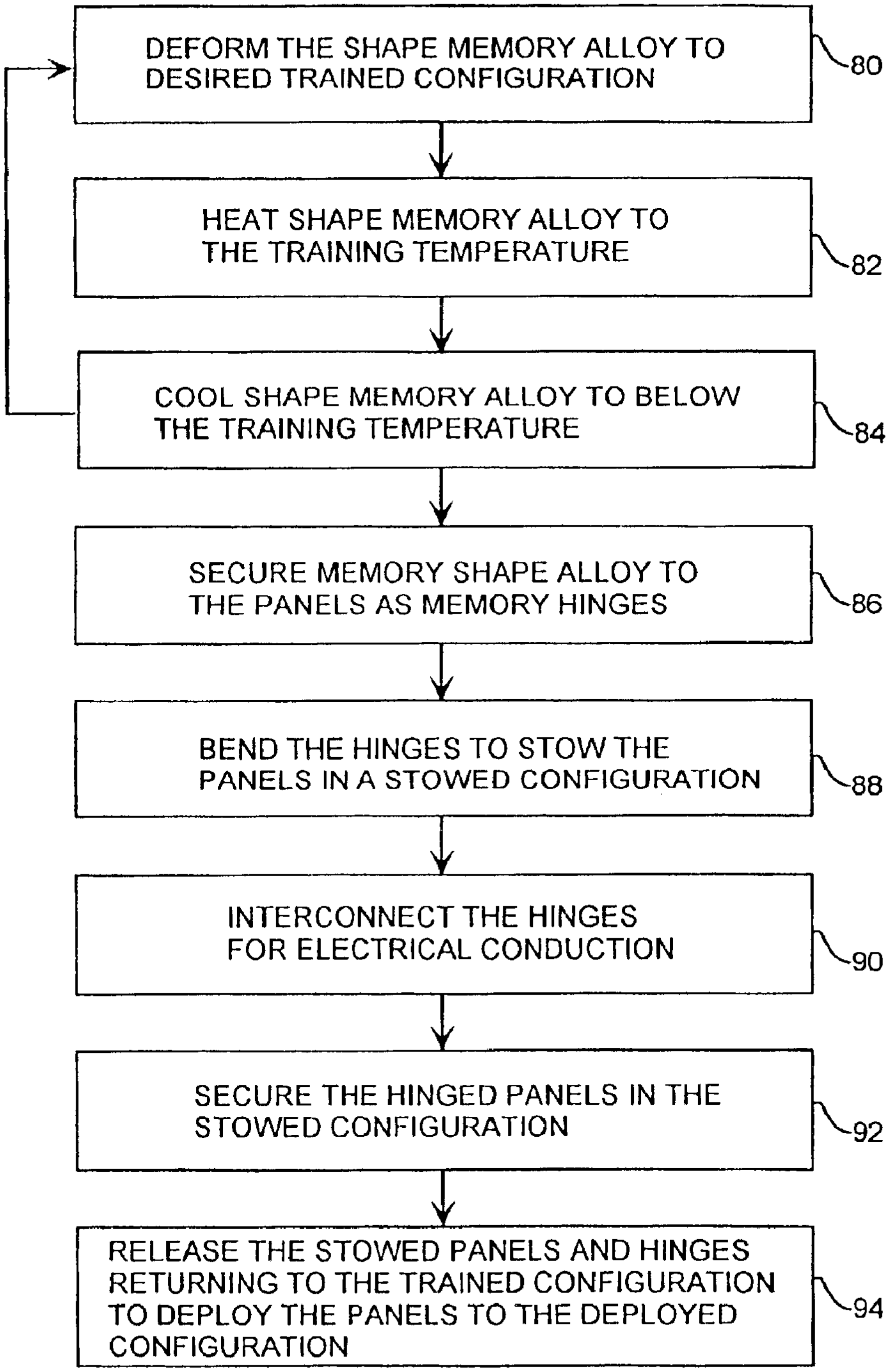
OPENED LATCH

FIG. 7B



LOCKED LATCH

FIG. 7C



METHOD OF DEPLOYING SHAPE MEMORY ALLOW HINGED PANELS

FIG. 8

SHAPE MEMORY METAL LATCH HINGE DEPLOYMENT METHOD

REFERENCE TO RELATED APPLICATION

The present application is related to applicant's copending application entitled "Power Sphere", Ser. No. 09/202,687, filed Apr. 2, 1999. The present application is a continuation of applicant's application entitled "Conductive Shape Memory Metal Deployment Latch Hinge Deployment Method", Ser. No. 09/886,416, filed Jun. 21, 2001 now U.S. Pat. No. 6,772,479B2, and is relatd to applicant's abandoned application Ser. No. 09/866,417 filed Jun. 21, 2001.

FIELD OF THE INVENTION

The invention relates to the field of metallurgy and metal alloy mechanical hinges. More particularly, the present invention relates to shape memory alloys trained as hinges for compressed stowing and recoiled deploying of three-dimensional enclosure of panels.

BACKGROUND OF THE INVENTION

The development of microsatellites and nanosatellites low earth orbits requires the collection of sufficient power for onboard instruments with low weight in a low volume spacecraft. Power generation methods for very small satellites of less that ten kilograms are desirable for these small satellites. Thin film solar arrays are useful power sources for small satellites. One problem faced by these low weight and low volume spacecraft is the collection of sufficient power for onboard instruments and propulsion. Body-mounted solar cells may be incapable of providing enough power when the overall surface area of a microsatellite or nanosatellite is small. Deployment of traditional planar rigid large solar arrays necessitates larger satellite volumes and weights and also requires extra apparatus needed for attitude pointing. One way to provide power to a small spacecraft is the use of roughly spherical deployable power system such as a solar powersphere that offers a relatively high collection area with low weight and low stowage volume without the need for a solar array pointing mechanism. The powersphere deployment scheme requires a deployment hinge that would move the individual hexagon and pentagon flat panels of the powersphere from a stacked configuration to an unfolded configuration where the individual panels would form a spherical structure resembling a soccer ball upon completion of the deployment sequence. The powersphere requires deployment hinges that serve to move the individual hexagon and pentagon flat panels of the powersphere from a stacked configuration to an unfolded configuration where the individual panels would form a spherical structure upon completion of the deployment sequence. Each of the panels has at least one hinge to adjacent panels. The panels should be locked into place and maintained at a precise angle relative to each connected panel to form the spherical shape. The flat hexagon and pentagon panels approximate an omnidirectional sphere. A combination of hexagon and pentagon shaped panels are used to form a soccer ball panel configuration when fully deployed. The interconnecting deployment hinges serve to position the individual flat panels of the powersphere from a stacked configuration to the deployed position forming the sphere of solar panels. The panels are hinged to one another and deploy to a precise angular position into the final shape that is preferably spherical rather than oblong or some other undesirable shape. Ideally this deployment mechanism would be fabricated from a thin film material that would have the properties to effect the mechanical positioning deployment and serve as structural elements for holding and locking each of the panels in respective positions about the powersphere.

Another type of microsatellite having an power enclosure uses a powerbox that is a three-dimensional solar array shape having rectangular shaped flat panels that would also deploy from a stowed flat configuration into a box shape configuration. The powerbox consists ideally of similarly shaped panels interconnected with hinges fabricated from a thin material that would have the properties to perfect the mechanical deployment and also be a structural element for locking each of the panels into respective positions. Hence, the powerbox would also require hinges that serve to move and lock the flat solar panels into position during deployment. Regardless of the final exterior shape of the three-dimensional power enclosure of a nanosatellite or microsatellite, a hinge mechanism is needed for deployment of the flat solar panels to cause the transition from the stowed configuration to the desired final array shape. Hence, there exists a need for positioning hinges between the flat panels forming a power collecting enclosure formed from the deployed solar array flat panels to realize any number of complex three dimensional solar array exterior surfaces used for solar power collection. However, the interconnecting hinges present a power conduction problem of routing collected converted power from the flat solar array panels to the payload of the spacecraft. Electrical conductivity of the hinge could be used to route signals and power about the power enclosure without the use of separate power lines for communicating power from the solar cell panels to the spacecraft payload. The hinges should be made of conventional materials. The hinge material could be a polymer as a flexure type hinge. But polymers are unstable and relax by cold flowing when stressed for any length of time. Polymer materials can also have undesirable outgassing properties and are generally not good electrical conductors. Polymer materials also have very low Young's moduli that reduces the deployment energy that can be stored in the hinge while stowed and later used to deploy and position the panels. Spring metals such as hardened stainless steel, beryllium copper or phosphorous bronze are commonly used as flexure type spring hinges. These spring metals have large Young's moduli, low outgassing characteristics, good electrical conductivity and will not cold flow, but spring metals have very small maximum elastic strains of 1% or less, and hence are unsuitable as deployment hinges because the steel spring hinges with interconnected panels will not stow compactly. These and other disadvantages are solved or reduced using the invention.

SUMMARY OF THE INVENTION

An object of the invention is to provide a deployment hinge for interconnecting and deploying panels from a stowed configuration into a deployment configuration.

Another object of the invention is to provide a deployment conductive hinge for mechanically and electrically interconnecting and deploying solar cell panels from a stowed configuration into a deployment configuration.

Yet another object of the invention is to provide an integral deployment latch for locking deployed panels into a deployment configuration.

Still another object of the invention is to provide a conductive deployment latching hinge for mechanically moving and locking and electrically interconnecting panels into a deployment configuration forming a power enclosure of a satellite.

Yet another object of the invention is to provide a compact hinge for interconnecting thin film solar panels, for enabling the panels to be stowed compactly, and for unfolding the panels into a large area three-dimensional array of a predetermined shape.

A further object of the invention is to store the energy necessary within an interconnecting hinge for unfolding and deploying the thin film solar array panels into a three-dimensional shape.

Still a further object of the invention is to use the hinges as the conductors for daisy chaining thin film solar cell panels together for conducting electrical power from the panels to a satellite power system.

Yet a further object of the invention is to provide an integral latch hinge for locking deployed panels in place for stiffening and strengthening a panel structure.

The invention is directed to a conductive hinge and latch for mechanically and electrically interconnecting and deploying panels into a deployed configuration. In a first aspect, the conductive hinge is made of a shape memory alloy with superelastic material properties enabling a small radius bend during stowage and flexible recoil return to a trained rigid hinge deployment position. In a second aspect of the invention, the hinge is further adapted into a latch for holding the hinge in a locked position after release and recoiling to rigidly locked panels into the deployment configuration. In a third aspect, the hinge is an electrical conductor enabling the hinge to function as a power bus for routing current through multiple interconnected panels to a power system for the satellite payload. The hinge is sufficiently conductive enabling the use of the hinge as a solar array power bus.

The multiple panels may be thin film flexible solar cell panels forming a hinged solar cell array that is deployed when the hinges are released from the bent stowed position into the latched rigid deployed position. Thin film solar cell arrays use extremely thin film amorphous silicon active materials. Hence, the hinge is also made equally thin as a thin film material. In order to stow thin film solar cell arrays in the most compact manner, the hinge is made of an extremely flexible superelastic shape memory alloy. To minimize the stowing volume, the hinges should be made as small as possible and the hinge will allow the panels to lie flat on top of each other.

The shape memory metal deployment hinge is preferably used for the square and rectangular solar panels forming a powerbox solar cell array, but can be used for other interconnected solar cell panel arrays such as the powersphere comprising hexagon and pentagon flat solar cell panels. The flat panels that make up a thin film deployable solar array enclosure are preferably stowed in the stack during the launch phase of a space satellite. Once on orbit, the stack of flat panels is deployed using the stored energy in the hinges so that the panels take a predetermined shape such as a rectangular powerbox or spherical powersphere. The hinge is capable of supplying the mechanical energy required to cause the stowed stack of flat panels to move and unfurl, that is recoil, to the deployed position.

The shape memory deployment metal hinge is preferably a thin sheet nitinol (NiTi) alloy used as a deployment spring, a structural support and a locking latch. Thin sheets of the nitinol alloy can be used as a spring and can be bent around extremely small radius without breakage or permanent deformation. The shape memory alloy hinge is disposed between adjacent thin film solar cell panels and can be bent to a small radius enabling the panels to stack one on top of the other with minimal spacing and therefore with maximum stowage efficiency. When stowed, the panels preferably rest on each other with no space in between the panels in order to be less susceptible to launch vibration damage and for stowage volume efficiency. The shape memory metal alloy returns when released to a trained precise angle required for the connection of the panels into the predetermined three-dimensional shape without sliding parts.

The hinge is a thin sheet of metal that maintains the correct angle and distance between adjacent solar cell panels when the array of panels is deployed. When the array is stowed, the metal is bent, that is flexed, within elastic limits. This stowage flexing stores energy that is later used to unfold the array after launch when the array is released. The hinge is a flexure type device that passively stores the energy required for deployment. After release, the hinges guide the panels during deployment and then maintains the desired deployment configuration once deployed. Thin sheets nitinol can bend around an extremely small radius without permanent deformation. When nitinol is raised in temperature to above the shape memory alloy transition training temperature, the nitinol will return to the trained configuration. When the trained sheet is released, the sheet springs back to the original shape. The on-orbit satellite releases the compressed stack of thin film panels that then unfold driven by the energy stored in the hinges located on the edges of each panel. To aid in rigidly holding the panels in place after deployment, the hinge is adapted to include an integral locking latch to hold the panel in the deployment configuration.

The shape memory metal alloy is formed as a thin film hinge structure that is simple in shape and easy to manufacture. The thin sheets of the nitinol alloy can be forged to provide the required precise final angle required to place each of the flat panels of the powersphere or powerbox into the deployment position. The superelastic shape memory alloy hinge is extended to include the function of a latch that locks the deployed structure in place for improved strength, and further functions as an electrical bus that conducts current from the solar cell panels to the payload of the satellite. Incorporating the stowage, deploying, latching and conductive functions in a single hinge element, the complexity and cost of the array is reduced, and the assembly process is simplified with improved reliability. These and other advantages will become more apparent from the following detailed description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a front view of a picosatellite having a deployed solar cell array.

FIG. **1**B is a side view of the picosatellite.

FIG. **2** depicts a solar cell array in a stowed configuration.

FIG. **3** depicts a memory alloy hinge having a small bend radius during stowage.

FIG. **4**A depicts a flat nitinol hinge.

FIG. **4**B depicts a scalloped hinge.

FIG. **5**A depicts a deployed hinge.

FIG. **5**B depicts a stowed hinge.

FIG. **6** is a graph of a nitinol superelastic stress-strain curve.

FIG. **7**A depicts a closed latch.

FIG. **7**B depicts an open latch.

FIG. **7**C depicts a locked latch.

FIG. **8** depicts the method of deploying shape memory alloy hinged panels.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the invention is described with reference to the figures using reference designations as shown in the figures. Referring to FIGS. 1A, 1B and 2, a picosatellite **10** has a powerbox **12** including a top **14** and bottom **16**. The powerbox **12** is formed by a plurality of rectangular panels including right side panels **18***a*, **18***b*, **18***c*, **18***d*, **18***e*, and **18***f*, collectively referred to as panels **18** and including left side panels **20***a*, **20***b*, **20***c*, **20***d* and **20***f*, collectively referred to as panels **20**. For convenience, only the right and left sides of the powerbox **12** are shown, but it is understood that the powerbox **12** may further include identical front and back sides of panels, not shown. The right side panels **18** are interconnected together and to the top **14** and the bottom **16** by hinge pairs **22**, **24**, **26**, **28**, **30**, **32** and **34**, also respectively shown as hinges **22***a* and **22***b*, **24***a* and **24***b*, **26***a* and **26***b*, **28***a* and **28***b*, **30***a* and **30***b*, **32***a* and **32***b*, and **34***a* and **34***b*. The panels **18***a* and **20***a* are respectively connected to the top **14** by hinge pairs **22** and **36**, and panels **18***f* and **20***f* are respectively connected to the bottom **16** by hinge pairs **34** and **48**. As shown, the powerbox **12** is almost completely unfolded from a compact accordion-like stowed configuration into a final deployment shape during accordion expansion and unfurling of the panels **18** and **20** during deployment of the powerbox **12** from the picosatellite **10**. The thin film solar panels **18** and **20** do not bend, but remain flat, during stowage and deployment.

Each of the adjacent thin film solar panels **18** and **20** are interconnected by two strip hinges, for example, panels **18***b* and **18***c* are interconnected by hinges **26***a* and **26***b*, that is, hinge pair **26**. To improve the electrical conductivity, the hinge can be plated at its ends with a metal of high conductivity such as silver. The silver plating is not applied to the shape memory alloy hinge in the bend area. One hinge is attached to the positive contact and another attached to the negative contact located on respective sides of the thin film solar panels. The hinges alternate between the active side, i.e. outward facing from the box, such as hinges **22**, **26**, **30**, and **34** and the inactive side, inward facing from the box, such as hinges **24**, **28**, and **32** of the thin film solar panels. This is necessary for mechanical success of accordion folding. To maintain electrical conductivity between the hinges in order to form a power bus down to the satellite power management system, conductive jumpers are used to electrically connect the active side hinge with the inactive side hinge. For example, jumper **21***a* provides continuity between hinges **24***a* and **26***a*. All hinge and jumper connections are done by electrically conductive solder. The hinges are interconnected by conductive jumpers, a pair of which is jumper pair **21**, one of which is jumper **21***a* electrically interconnecting hinge **26***a* and the other of which is jumper **21***b* electrically interconnecting hinge **26***b*. The hinges are interconnected to the jumpers that may be metal clips for electrically connecting together one hinge on one active side of a panel to another hinge on the other inactive side of the panel. The panels **18** and **20** are secured to each other by conductive solder joints, one of which is shown as joint **49**, and secured to the top **14** and bottom **16** by respective solder joints **51** and **52**, respectively. When released, the panels **18** and **20** unfurl and accordion expand from a compressed stacked configuration to form a rigid box shape of the powerbox **12**.

Referring to FIGS. **1** through **5B**, and two panels **54** and **56** when in the deployed position return to a trained relative angle, for example, of 180° as in FIG. **3**, or 142° as shown

in FIG. **5A**. To minimize the hinge stowed diameter d, the elastic strain limit of shape memory alloys is large. A further benefit of shape memory alloys is the inherent damping that occurs within the material as it flexes. This will remove unwanted array motion following deployment or due to environment disturbance forces. Another benefit of shape memory alloy is that it is electrically conductive allowing the power generated in the solar panels connected by the hinges to be passed down through them ultimately to the satellite power management system. When in the stacked stowed configuration, all of the hinges **58** are folded to a small radius d that is preferably only slightly larger than the total thickness of the panels **54** and **56** and hinges **58**, in addition to the solder joints **66** and **68**, so that the panels **54** and **58** can be accordion stacked in a compressed state that minimizes stowage volume when in the stowed stacked configuration. The hinge **58** can be trained to assume several deployed shapes such as the shapes of a flat hinge **60** or a scalloped hinge **62**. The scalloped hinge **62** offers increased rigid strength when released from the stowed position and fully returned to the final deployed position. That angle is arbitrary and is determined by the desired final shape of the deployed array once all the hinges are open. For the powerbox example, the trained angle is 180° because it is desired that the powerbox walls be straight. It is conceivable that the powerbox walls could be designed to bow outwards in which case the trained angle would be greater than 180°. In the case of the powersphere thin film solar array shape, the **32** panels that comprise the array have hinges between them trained to an angle of 142° in order to realize a spherical shape when all of the panels are deployed. For both the powersphere and powerbox array shapes, the stowed angle of a hinge is always 0°.Furthermore the hinge, by being soldered to the panels, holds the distance between cells fixed. This also effects the shape of the final deployed array.

The shape memory metal deployment hinge **58** can be fabricated out of 0.7 mm thick foil of nitinol (NiTi) alloy. A strip of the shape memory alloy foil may be one quarter inch wide. The strip is disposed in a mold, not shown, that is then heated to approximately 500° C. and forged over the mold to train the foil to the relative angle between the two panels **54** and **56**. The NiTi alloy foil in the fixture would together then be quenched in order to cause the NiTi alloy to permanently have the relative angle as shown for example in FIG. **5A**. The two panels **54** and **56** are bonded or soldered to the NiTi alloy foil strip completing the hinge assembly. The hinge **58** can then be folded back on itself to form a zero degree fold of the hinge so that the panel **54** and **56** are parallel to each other for compressed stacking during stowage.

A hinge **58** is a flexure hinge that is made as a very thin planar sheet. The hinge **58** should have a large maximum elastic strain limit, for example of up to 8%, a bending axis for zero-power deployment utilizing the energy stored in the elastic strain when stowed. The hinge **58** also offers damping of oscillations of the hinge due to the hysteresis in the stress-strain cycle. The hinge **58** is electrically conductive for routing power from the interconnected panels **54** and **56**. Also, the formed angle of any hinge **58** can be independently determined from hinge to hinge to form an arbitrary enclosed volume or surface of panels that are preferably flat panels **54** and **56**.

Referring to FIGS. **1A** through **6**, nitinol has a maximum elastic strain limit that may be as high as 8%. The maximum elastic strain determines the smallest bend diameter of the stowed flexure hinge **58**. A nitinol hinge will stow thin film solar cells with improved packaging efficiency. The nitinol flexure hinge allows for a slow deployment of a structure. The rate of deployment can be further controlled by ohmically heating the hinge when conducting power through the hinge. Deliberate heating for subsequent actuation is not needed when the hinge is used above the shape memory alloy transition temperature or used as a power bus conducting power that will slowly warm the hinge to control the deployment rate. Hence, the nitinol hinge can be used as a hinge between the panels as well as an electrical bus to conduct the power. As that current passes through the nitinol hinge, the resistive losses cause the hinge to heat to deploy the panel at a predetermined rate. The flexure hinge of very thin nitinol material allows the most efficient packaging of thin film solar cells for a deployable array. The hinge can be configured for intricate arrays because no elaborate pulley mechanisms are required. That is, each panel unfolds under power of the stored energy in the flexing hinge.

Referring particularly to FIG. **6**, superelastic shape memory alloys have an elastic strain region that is elongated as shown. Initially, the stress is proportional to the strain. However, at a point where the elastic strain limit of a nonsuperelastic metal is reached, the shape memory alloy performs a reversible crystal structure phase change. As a result, the elastic strain limit ϵ_m is shifted substantially along the deformation strain axis, for example, to almost 8% for NiTi in tension. Practically, the 8% is only valid for one superelastic tension cycle of the metal. When more cycles are required, the maximum operating strain should be reduced, for example, for one hundred cycles, a maximum tensile strain of 6% may be used. The nitinol NiTi alloy ratio used is 55.8% Ni and has a transformation temperature A_f=0° C. As long as the temperature of the alloy is above A_f, then the material will exhibit stress-strain behavior bounded by the stress-strain curve. In the open position, the hinge moves precisely to the desired final angle. The inside bend diameter d is related to the deformation strain of the material and the thickness of the material. That is, $d=t(1-\epsilon)/\epsilon$ where ϵ is the deformation strain of the material and t is the thickness. A diameter of d=0.016 inches is sufficient to package a double-sided thin film solar cell array in accordion stowage, where each cell is 0.010 inches thick. However, it is not small enough for the single-sided thin film solar cell array where each cell is 0.006 inches thick. For this, a NiTi sheet even thinner than t=0.001 inches will be needed in order that the array will efficiency stow with the panels in abutting each other in planar contact.

Referring to all of the figures and more particularly FIGS. **4**B, **7**A, **7**B and **7**C, a second aspect of the invention is the latch hinge. The scallop hinge **62** and the coil hinge **70** function as both a hinge and a latch. The scallop hinge **62** has a first hinge axis defining a stowage bend, and a second latch axis defining the scallop bend, and as such, the scallop hinge **62** is a form of the latch hinge **70**, unfolding about two different axes. The coil hinge **70** also has a first hinge axis defining the stowage bend and a second latch axis defining a coil bend. The coil latch **70** functions by rolling up and forming a coil whose axis is orthogonal to the hinge stowage axis and thereby prevents any further hinge angular motion once the latch fully coils. The latch **70** is integral to the hinge because a latch portion is formed by cutting the shape memory alloy sheet used for the hinge so that the hinge foil has a tab **70** that can coil. That tab is trained to roll up to a coil when the hinge is deployed. In the stowed position the coil is unrolled and folded to the same radius as the hinge, thereby preventing latching during stowage. The hinge function is characterized as having a traverse bend with the hinge axis of bending orthogonal to the aligned interconnected panels **54** and **56**. The latch function is characterized as having a longitudinal bend with the latch axis of uncoiling parallel with the aligned interconnected panels **54** and **56**.

The hinge and latch axes of bending need only be at a different orientation from each other to add strength to the hinge to lock the panels in place. In the preferred form, the hinge bending axis is orthogonal to the latch coil axis. The latch hinges **62** and **70** firstly unbend along the traverse hinge axis to angularly position the panels **54** and **56** relative to each other. The latch hinges **62** and **70** then unbend along the longitudinal latch axis to lock the panels in place at that relative angular position. The scallop hinge **62** is characterized by having a longitudinal scallop bend and the coil hinge is characterized by having a longitudinal coil bend.

Referring to FIG. **8**, in forming the hinges, a suitable sized hinge is placed in a fixture, not shown, and raised to a training temperature **80** through the crystal transition phase. When the material is placed in fixture and strained, stress forces are created in the material. The stress forces are relieved when the material is heated to the training temperature. The fixture can be a mold that holds the hinge when deformed **82** into the desired shape with the desired bend angle when the shape memory alloy material is in the austeutit phase. The material is then quenched and cooled down **84** to below the training temperature so as to complete the training of the material. Many shape memory alloy hinges are needed so that steps **80** through **84** are repeated a number of times to train several hinges. The hinges are secured to the panels by bonding and or soldering or both. Then, the hinges are forcibly folded and elastically strained as the panels are folded into the stowed configuration, and, held in the stowed configuration so as to store potential energy for subsequent return to the trained configuration after release. The hinges will return to the trained configuration when released dissipating the potential energy during hinge unfolding motion. The hinges may be further interconnected together, using electrical jumpers for example in the case of conducting collected solar power. The hinged panels are then secured in the stowed position for subsequent release. The securing means may be a fuse wire that is opened when desired. The hinged panels are then released with the hinges returning to the trained configuration as the panel move to and are latched into the deployed position.

The construction of an interconnected thin film solar cell panels can be made in any two-dimensional shape. Thin film cells are very flexible when constructed around a thin polyimide core. Using monolithic interconnects, cells can be partitioned and connected in series thereby raising the voltage seen at the contacts. The back side of the cells is electrically isolated with both electrical contacts located on the same side as an active region. The next step in constructing the rectilinear array is to build the array in z-folds. First, the rectangular thin film solar cells are laid out in a row. The silver plated superelastic NiTi alloy strips are soldered to the contacts on the front side of each end of the solar cells. The unplated bent hinge regions of the strips are aligned with the gap between adjacent cells. Next, the jumpers are installation interconnecting the strips. Adjacent hinges are on opposite sides of the solar cell panel. The alternating opposite side displacement of the hinges prevents any hinge from being located on the inside of a bending fold. The hinges are located on the outside of each bend. While this preserves the integrity of the mechanical hinge, it fragments the electrical bus of interconnecting hinges. Thus, very thin jumpers of copper or silver foil are installed to electrically connect the hinges together for continuity as a power bus. The final step is the connection of top and bottom z-folded panels to the top and bottom of the picosatellite stowing the array. A fuse wire, not shown, can be used to hold the panels in the stowed configuration and subsequently fired for releasing the hinges.

The present invention is directed towards memory shape alloy latch hinges for interconnecting, power distributing, deploying, and latching solar cell panels forming a power source, but can generally be applied to any set of panels desired to be interconnected for forming a contiguous surface. Those skilled in the art can make enhancements, improvements, and modifications to the invention, and these enhancements, improvements, and modifications may nonetheless fall within the spirit and scope of the following claims.

What is claimed is:

1. A method of forming a hinge for moving panels from a stowed position to a deploy position for forming a hinged surface of panels, the method comprising the steps of,

heating a shape memory alloy to above a crystal transition temperature and above a training transition temperature,

deforming the shape memory alloy into the hinge when above the training temperature to train the shape memory alloy to return to the deployed position, the hinge being trained to return to the deployed position when released from the stowed position,

cooling the shape memory alloy to below the training transition temperature and above the crystal transition temperature, the shape memory alloy being in a superelastic state between the training transition temperature and the crystal transition temperature,

securing the shape memory alloy into the stowed position in the superelastic state, the shape memory alloy returning to the deployed position when released, and

releasing the shape memory alloy in the stowed position, the shape memory alloy being in the superelastic state when returned to the deployed position.

2. The method of claim **1** further comprising the step of,

deforming the shape memory alloy about a hinge axis, the deforming of the shape memory alloy above the training temperature trains the hinge to return to the deployed position by unbending about the hinge axis, the hinge bends about the hinge axis when placing the hinge in the stowed position, the hinge returning to the deployed position when released from the stowed position in the superelastic state.

3. The method of claim **1** wherein the securing step comprises the steps of,

securing a proximal end of hinge to a first panel of the panels,

securing a distal end of the hinge to a second panel of the panels,

bending the hinge to position the hinge and the first and second panels in the stowed position, and

securing the first and the second panels to each other for securing the hinge in the stowed position in the superelastic state.

4. The method of claim **1** further comprising the step of,

deforming the shape memory alloy about a latch axis, the deforming of the shape memory alloy to above the training temperature trains the shape memory alloy to lock in the deployed position, the hinge being trained to unbend about the latch axis to lock the hinge into the deployed position.

5. The method of claim **1** further comprising the step of,

deforming the shape memory alloy about a hinge axis, the deforming of the shape memory alloy above the training temperature trains the hinge to return to the deployed position by unbending about the hinge axis, the hinge bends about the hinge axis when placing the hinge in the stowed position, the hinge returning to the deployed position when released from the stowed position in the superelastic state, and

deforming the shape memory alloy about a latch axis, the deforming of the shape memory alloy to above the training temperature trains the shape memory alloy to lock in the deployed position, the hinge being trained to unbend about the latch axis to lock the hinge into the deployed position, wherein

the hinge is trained to unbend about the hinge axis and about the latch axis to deploy and lock the hinge into the deployed position for locking the panels in the deployed position, and

the latch axis is orthogonal to the hinge axis.

6. The method of claim **1** wherein,

the panels are solar panels, and

the shape memory alloy is nitinol.

7. The method of claim **1** further comprising the step of,

plating the shape memory alloy to increase the conductivity of the shape memory alloy.

8. A method of forming a hinged surface of panels, the method comprising the steps of,

forming hinges from a shape memory alloy, each of the hinges having a proximal end for securing to a first panel of the panels and a distal end for securing to a second panel of the panels,

heating each of the hinges to above a training temperature of the shape memory alloy,

deforming the hinges when above the training temperature to train the hinges to a deployed position, the hinges being trained to return to the deployed position about a hinge axis when released from a stowed position, and

cooling the hinges to below the training temperature and above a crystalline transition temperature, the hinges being in a superelastic state,

securing the hinges to the panels, the panels forming the hinged surface when interconnected together by the hinges when in the deployed position,

securing the panels together for securing the hinge and the panels in a stowed position, and

releasing the panels for releasing the hinges that return to the trained position in the superelastic state.

9. The method of claim **8** wherein,

the shape memory alloy is conductive, and

the panels are solar panels,

the method further comprising the steps of,

interconnecting together the panels and hinges for forming a power bus for conducting current from the solar panels.

10. The method of claim **8** further comprising the step of,

deforming the hinges when above the training temperature to train the hinges to unbend about a latch axis for locking the hinges into the deployed position for locking the panels into the deployed position.

11. The method of claim **8** wherein,

the shape memory alloy is nitinol,

the panels are solar panels, and

the hinged surface is a solar cell array.

12. The method of claim **8** wherein,

the shape memory alloy is nitinol,

the panels are solar panels, and

the hinged surface is a powerbox.

13. The method of claim **8** wherein,

the shape memory alloy is nitinol,

the panels are solar panels, and

the hinged surface is a powershere.

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